ON THE SCIENCE OF WEIGHING AND MEASURING, AND THE STANDARDS OF WEIGHT AND MEASURE*

VII.

WEIGHING AND MEASURING INSTRUMENTS, AND THEIR USE

THE instrument universally used for weighing is the balance, with its various modifications. It serves to determine the weight of bodies by comparison with a body of known weight, such as a standard weight. The simplest form of balance is a beam made to vibrate upon a centre or axis of motion, with pans hanging from the extremities of the two arms of the balance. These two pans hold the bodies compared, and their equality or difference of weight can thus be determined.

Balances are of two kinds:—1. Ordinary balances with equal arms, which have the beam suspended by the middle. If an equal-armed balance is accurately adjusted, so that the beam is exactly horizontal when the pans are empty, the beam will also be horizontal, and the balance will be in equilibrium when equal weights are placed in the pans. 2. Balances with unequal arms, in which the beam vibrates upon the centre of motion placed more or less near one of the extremities. In both of these kinds of balance the beams are levers of the first order, the fulcrum upon which the beam vibrates being placed between the power and the weight, that is to say, between the extremities of the beam which support the bodies compared. On the principle of the lever, the power of any weight to move a balance is proportionately greater according as the part of the beam which supports that weight is more distant from the fulcrum or centre of motion of the balance. Hence it follows that the power of the weight to move a balance is in a ratio compounded of the weight itself and of its distance from the centre of motion of the balance. A multiplying or proportionate balance may consequently be constructed for determining the weight of a body placed in the pan suspended from the shorter arm of the bearer, and required to be equal to any multiple of a given unit weight placed in the pan suspended from the longer arm of the beam, termed the weight pan. For this purpose, if the beam be divided into, say three equal parts, and the centre of motion be placed at the first division, one pound placed in the weight pan will form an equipoise with two pounds placed in the other pan, and so on. This principle is greatly extended in larger weighing machines by lengthening the longer arm, through the use of compound levers, so that one pound can be made to form an equipoise with 100 pounds or more.

The ancient Roman balance is perhaps the earliest form of a well-constructed multiplying balance, and corresponds with our modern steelyard. It has been remarked by Sir Gardiner Wilkinson that no instance has been found of the existence of the steelyard before the Roman era. But the principle of its construction was in use amongst the ancient Egyptians, who ascertained the weight of articles suspended from different parts of a scale beam by means of a heavy determinate weight placed in one scale. The Roman balance consists of a determinate weight attached to the longer arm of the beam, and made to traverse along a number of divisions marked upon it. The multiplied power of the traversing weight when resting on the several sub-divisions, as they increase in distance from the centre of motion, is indicated by corresponding figures upon the graduated beam.

The following figure (taken by permission from the "Imperial Journal of Art," vol. i. p. 85) represents an ancient Roman balance of an elegant form, found at Pompeii, and in use A.D. 77. It is described as having the graduated divisions on the longer arm of the beam marked with Roman numerals from X. to XXXX. (probably Roman pounds), and with a V. on the half of each decimal series, the smaller subdivisions being also marked. The inscription on the shorter arm of the beam (shown in a separate and enlarged figure) denotes its having been proved at the Capitol in the 8th of Vespasian Emperor Augustus, and in the 6th Consulate of Titus Emperor Augustus his son. This steelyard is consequently a duly verified standard weighing machine.

For the justness of an equal-armed balance, it is requisite (1) that the points of suspension of the pans from the beam be exactly in the same line as the centre of motion; (2) that these points be precisely equidistant from the centre of motion; (3) that the arms be as long as conveniently may be, in relation to their thickness and the weight they are intended to carry, in other words, consistently with the stability of the balance; (4) that there be as little friction as possible at the centre of motion and the points of suspension; (5) that the centre of gravity of the beam be placed a little below the centre of motion.

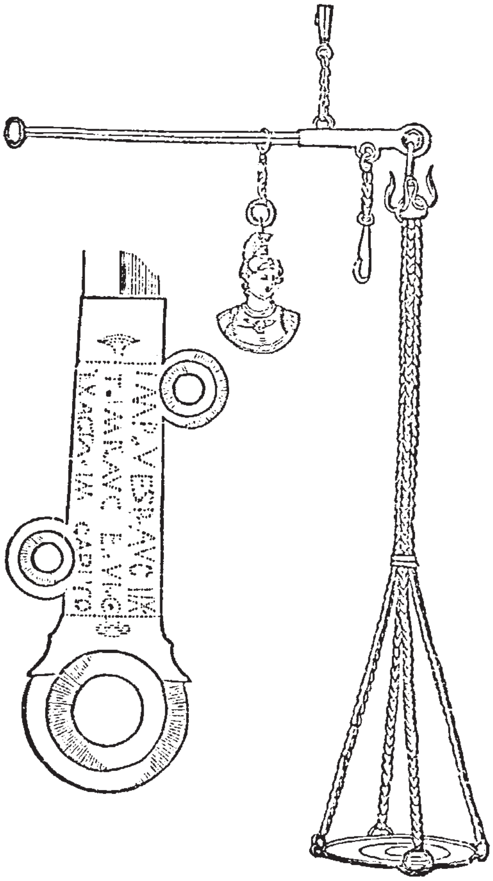

FIG. 15.—Ancient Roman Balance.

The fulcrum upon which the beam of a balance rests is formed with a steel knife edge, and the two pans at its extremities are hung upon similar knife edges. In ordinary trade balances, these knife edges, are placed in contact with steel bearings having a spherical curve. But in the practical construction of balances of a high degree of sensibility, such as are required for scientific purposes or for the comparison of standards in which very minute differences of weight are to be determined, there are many circumstances to which attention is requisite, that may properly be neglected in balances used for commercial purposes. In such balances of precision great care is required in the adjustment of the knife edges. They are first made quite sharp, and are then slightly rounded with a fine hone or a piece of buff leather. On the regular form of this rounded edge, the excellence of the action of the balance very much depends. The central knife edge rests upon an agate or polished steel plane, whilst the two pans are suspended from agate or steel planes bearing upon the knife edges at the ends of the beam. In order to preserve the nice adjustment of the knife edges, they are never allowed to rest upon their bearings, except when weighings are made. At all other times, the beam and pans are separately supported upon a brass frame attached to the column of the balance, but moveable in a vertical direction upon it. When required to be put in action the support is gradually lowered by means of a lever handle, and the knife edges are brought upon their bearings.

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* Continued from p. 491.

The principal cause of discordances in the results of successive weighings with a balance of precision arises from the risk of the knife-edges not being brought again to exactly the same position on the plane bearings, after the balance has been stopped and again set in action. The most perfect balance is that which varies least in the points of contact between the knife-edges and their bearings during successive weighings. For the attainment of this very important requirement, the supporting frame is furnished at each of its extremities with two pins terminating in cones and made to fit exactly into corresponding conical holes in the plane bearings, at each of the extremities of the beam. The pins and holes are in a line normal to the axis of the beam. The points of these four cones are all in the same horizontal plane. As the movement of the supporting frame in a well-constructed balance of precision is always in the same vertical line, being guided by a vertical rod fitted to a cylindrically drilled hole in the column of the balance, the knife-edges and their bearings are always brought into contact in the same relative positions. Balances of precision are always enclosed in plate glass cases, with a view both to their preservation, and to keep the balances as far as possible from being affected in their action by draughts of air, alternations of temperature, &c.

As to the theory of the relative positions of the centre of motion and the centre of gravity of a balance, it is to be remarked, (*a*) If the fulcrum be placed in the centre of gravity of the beam, and the three edges be all in the same right line, the beam of the balance will have no tendency to one position more than another, but will rest in any position in which it may be placed, whether the pans be suspended to it, or not, and whether the pans be empty or equally loaded. (*b*) If the centre of gravity of the beam, when level, be immediately above the fulcrum, it will upset with the smallest action; that is to say, the end which is lowest will descend; and it will descend with the greater velocity, according as the centre of gravity is higher, and the points of suspension less loaded. (*c*) But if the centre of gravity of the beam be immediately below the fulcrum, the beam will not rest in any position but when level; and if disturbed from that level position, it will vibrate, and at last come to rest in a horizontal position. Its vibrations will be quicker, and its tendency to the horizontal position stronger, the lower the centre of gravity, and the less the weight upon the points of suspension.

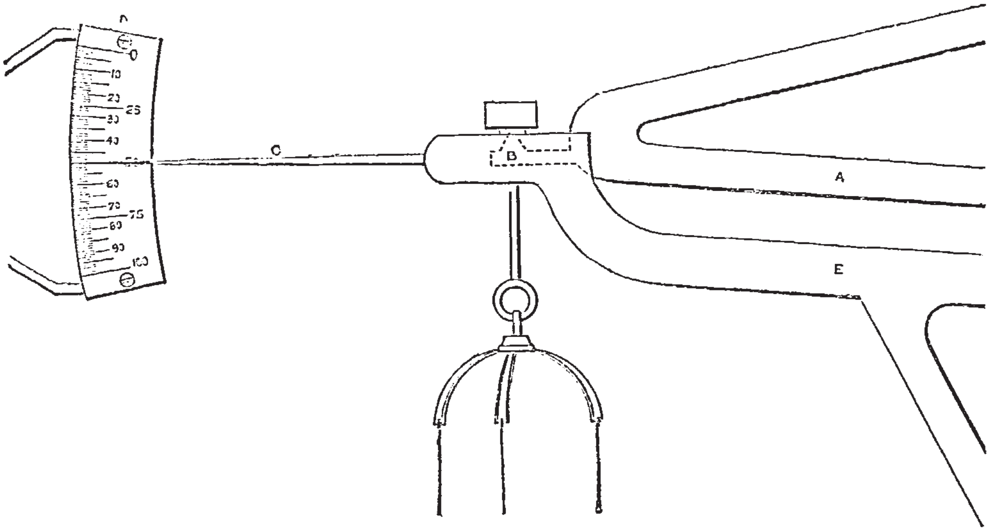

FIG. 16.—Index Scale, &c., of No. 3 Balance of Standard Department.

Again, as to the relative position of the central knife edge, which constitutes the fulcrum of the beam with the line joining the two outer knife edges, which form the points of suspension, it is further to be remarked, (1) If the fulcrum be below the line joining the points of suspension, and these be loaded, the beam will upset, unless prevented by the weight of the beam tending to produce a horizontal position, as shown in (*c*). In such case, small weights will form an equipoise. In case of (*a*), a certain exact weight will rest in any position of the beam; and all greater weights will cause the beam to upset, as in (*b*). (2), If the fulcrum be above the line joining the points of suspension, the beam will come to its horizontal position, unless prevented by its own weight, as in (*b*). (3) If the centre of gravity be nearly in the fulcrum, all the vibrations of the loaded beam will be made in lines nearly equal, unless the weights be very small, when they will be slower. The higher the fulcrum the quicker will be the vibrations of balances, and the stronger the horizontal tendency.

It is thus evident that the nearer the centre of gravity of the beam is to the centre of motion, the more delicate will be the balance, and the slower the vibrations. The tendency to a horizontal position is therefore increased by lowering the centre of gravity, in which case it will also require a greater additional weight to cause it to turn or incline to any given angle, and it is therefore less sensible with a greater load. The fixing of the centre of motion in a balance is consequently of peculiar importance, for on this depends the ease with which it will be affected by a smaller weight, and the readiness with which the beam will return to a horizontal position. And it will be seen that the best position of all is that in which the centre of motion is a little above the centre of gravity. Even in this, it should be proportioned to the distance of the weights from the fulcrum, and the amount of the load, which can only be attained in different beams by practice and experience. In order to regulate the centre of gravity in balances of precision, they are made to carry a small weight either over or under the centre of motion, which is moveable by means of a screw.

From what has been said it would appear that if the arms of a balance be unequal, weights which form an equipoise will be unequal in the same proportion. But although for many purposes the equality of the arms of a balance is advantageous, yet a balance with unequal arms will weigh just as accurately as one with equal arms, provided the standard weight itself be first counterpoised, then taken out of the pan, and the weight to be compared be substituted and adjusted against the counterpoise. Or when proportional quantities only are required, they may be weighed against standard weights, taking care always to put these weights in the same pan. But in this case it is indispensable that the relative lengths of the two arms of the beam continue invariable. For this purpose, either the three knife-edges should be truly parallel, or the points of suspension and support be always in the same part of the knife-edge.

If the beam of an equal armed balance be adjusted so as to have no tendency to any one position, as in (*a*), and the pans be equally loaded, then if a small weight be added to one of the pans, the balance will turn, and the point of suspension move with an accelerated motion, similar to that of falling bodies, but very nearly as much slower in proportion as the added weight is less than the whole weight borne by the fulcrum. The stronger the tendency to a horizontal position in a balance, or the quicker its vibrations—see (*c*) and (2)—the greater additional weight will be required to cause it to turn or increase to any given angle. If a balance were to turn with $\frac{1}{10000}$ part of the weight, it would move at the quickest, 10,000 times slower than a falling body; that is to say, the pan containing the weight, instead of falling through 16 ft. in a second of time, would fall only through $\frac{1}{250}$ part of an inch; consequently all accurate weighing must be slow.

Long beams have been generally recommended because the quantity of motion in a given body varies as its distance from the fulcrum; and therefore the greater the distance, the most distinguishable will be the motion arising from any small difference between the weights compared. On the other hand, there are certain advantages in the quicker angular motion, greater strength, and less weight of a short beam.

The pans of a balance should be suspended in such a manner that in all positions the corresponding cords or rods may be parallel to one another; else the weights, though equal, will not be in equilibrium.

In ordinary commercial balances, the preponderance of either pan is indicated by a slender rod attached to the beam immediately over its centre of motion in a line perpendicular to the axis of the beam, and moveable freely between the two forks of the handle. It is called the tongue of the balance, and the degree of preponderance of either pan is shown by the greater or less deviation of the tongue from its normal vertical position. In balances of precision, the index is a longer needle-rod, fixed either in a line perpendicular to the axis of the beam, and below its centre of motion, or in a line in continuation of its axis. In both cases the pointer moves along a graduated index. But an index placed perpendicular to the beam affects its equilibrium when turning from its horizontal position; the momentum of the index being measured by its weight multiplied with the distance of its centre of gravity from a line perpendicular to the horizon. The error thence arising may, however, be corrected by continuing the index-rod or counterpoising it, on the opposite side of the beam.

The finest balances of the Standards Departments have the index pointer in the line of the axis of the beam, as shown in Fig. 16, which represents the left-hand side of the balance, the right-hand side being similarly furnished with a pointer and index scale.

This is the medium size of six of the finest balances of the Standards Department, constructed by Mr. Oertling. For all weighings of standards requiring special accuracy, the highest and lowest points reached by the needle in each oscillation of the balance are read on the index scale through a telescope fixed at about 5 ft. distance, by which means each reading can be satisfactorily taken by estimation to one-tenth of a division of the scale.

Another balance of the Standards Department is one constructed by Barrow, and used by Prof. Miller for all his weighings during the construction of the new Standard pound. The knife-edges work upon quartz planes. Index scales marked on a thin and nearly transparent slip of ivory are fixed immediately above each end of the beam and oscillate with it. They are of the following form and size. These scales are illuminated by a candle placed at a little distance either in front of or behind the balance case, a lens being interposed; and they are viewed through compound microscopes having a single horizontal wire fixed in the focus of the eye-piece. The microscopes are fixed to the front of the balance-case, and as the observer must necessarily be close to the microscopes during weighings, a second glass screen is interposed between him and the front of the balance-case, having openings opposite the eye-pieces of the microscopes.

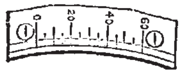

FIG. 17.—Index Scale of Barrow's Balance.

The weight intended to be carried by each of these balances, and the mean value of one division of the index scale, or the weight represented by it, when the balance is fully loaded, may be seen in the following table:—

Balance.	Length of Beam.	To carry in each pan.		Mean value of 1 div. of Index Scale.
	In.	Avoir.	Troy.	Grains.
No. 1	36	56 to 14 lbs.,	or 500 to 200 oz.	0·15
No. 2	24	7 to 2 lbs.,	or 200 to 20 oz.	0·02
No. 3	15	1 lb. to 2 oz.	or 20 to 2 oz.	0·0015
No. 4	10	1 oz. and under,	1 oz. and under	0·0008
No. 5	10	30 gr. and under.		0·0002
No. 6	20	1 kilo. and under.		0·0015, or 0·1 mgr.
Barrow's	...	1 kilo. and under.		0·005, or 0·3 ,,

There is another much larger balance which was originally constructed for weighing the contents of water of the Imperial Standard bushel, the total weight in each pan being nearly 300 lbs. The beam of this balance is of mahogany, 67¼ in. in length. With a full load, the mean value of 1 div. of the index-scale is 0·4 grain. This balance, like the other, is enclosed in a large plate-glass case.

In all these balances, the value of a division varies from time to time according to the weight in the pans, the condition of the balance, the state of the atmosphere, &c., and in all very accurate weighings it is desirable to determine the value for each comparison, by an additional weighing, after a very small weight, accurately verified and equal to a few divisions only of the balance, has been added to one of the pans, so that its effect on the reading of the index scale may be noted. The above stated values indicate nearly those found when the balance is in good working condition, and fairly weighted.

All these balances, when in equilibrium, will turn with a very small additional weight, equal to the value of two or three divisions, placed in one of the pans. They are exceedingly sensitive, for the sensibility of a balance is to be measured by the least amount of additional weight placed in either pan that is sufficient to turn the index-pointer from its normal position, when the balance is in equilibrium, and by the greatest amount of deviation from the normal position which is produced by a very small difference in the weights.

H. W. CHISHOLM

(*To be continued.*)

CINCHONA CULTURE [*]

FEW subjects have been so frequently before pharmaceutical readers during the past ten or fifteen years as the efforts of the governments of Holland and Great Britain to introduce the various species of Cinchona into their respective colonies. It would be hardly possible to overrate the importance of the enterprise, and it is one that interests alike the pharmaceutist, the botanist, and the votary of economic science. The records of progress which have been made public are so scattered and unconnected, the opinions and reports so conflicting, that it has been difficult for the general reader to retain the thread of the story or to arrive at any very clear estimate of the present position and prospects of the undertaking. The earliest steps in this great experiment in acclimatisation date back to a period before that which we have had under review, but so far as results are concerned, the subject is one which pertains essentially to the past few years, and I propose to place before you, in as few words as may be, and unencumbered by the controversial matter with which its literature abounds, an outline of the beginning of the enterprise and of its present practical aspect.

The initiative in Cinchona cultivation was taken, as you well know, by the Dutch Government, whose efforts were directed to its introduction into the Island of Java. The first Cinchona trees which were sent out to that colony were a few specmens of *C. Calisaya* [†] raised from seeds collected by M. Weddell in Bolivia, and forwarded by a firm of nurserymen in Paris in exchange for rare Javan plants. In the same year, 1852, the Dutch Government were induced to send M. Hasskarl, a gentleman previously attached to the Botanic Gardens at Buitzenorg, on a mission to South America, for the purpose of collecting plants and seeds. During the two years following M. Hasskarl pursued his labours, and succeeded in forwarding consignments from some parts of Peru, the Cinchona districts of Bolivia being for the most part closed against him; and his efforts were supplemented as to the New Granada species by the assistance of Dr. Karsten. The resulting collections were sent in part direct to Java, and the remainder to Amsterdam for re-shipment. I need not dwell on the mishaps and disappointments inevitable in so new and difficult an enterprise—it is sufficient to note that within three or four years, that is by the middle of 1856, upwards of 250 plants, almost exclusively of two species, *C. Pahudiana* and *C. Calisaya*, were flourishing in the Java plantation as the outcome of the expedition. In the same year, with wise forethought, an accomplished chemist, Dr. De Vrij, was sent out to conduct chemical observations on the growing barks.

We may pass over the long series of troubles that attended the early efforts of those in charge of the trees, the ravages of insects, the destruction of young plants by rats, the devastation committed by wild cattle and rhinoceroses, and, above all, the difficulties dependent on climate, which eventually necessitated the transplantation of nearly the whole of the trees from the locality first chosen, on the north side of the mountain range, to one with a southern aspect. We will pass on, I say, to the year 1863, and we shall find that the total number of Cinchona trees in Java was then 1,151,810. Of these about 99 per cent. were of the species know as *C. Pahudiana*, the remainder comprising about 12,000 of *C. Calisaya* and trifling numbers of four other species. This proportion was unfortunate, for the bark of *C. Pahudiana* was found to be deficient in alkaloids, and therefore supposed to be valueless, and by decrees dated 1862 and 1864 its further culture was ordered to be forthwith stopped.

We may now turn to the steps taken by the British Government in the same direction.

Dr. Ainsley, in his work on "Materia Medica," was perhaps the first to suggest the idea of the acclimatisation of the Cinchona in India, and, as early as 1839, Dr. Forbes Royle especially indicated the Neilgherry and Silhet mountains as eligible for the experiment. Appeals were subsequently made to the East India Company by Mr. Grant and Dr. Falconar, with the object of inducing them to take up the matter, and in 1852 instructions were sent to the British consular agents in South America to endeavour to procure seeds of the various species, but without much real effect. Dr. Royle, as Reporter on the Products of India, continued to urge the subject on the attention of Government up to the time of his death, and eventually, in 1859, at the instance of his successor in office, Dr. Forbes Watson, the services of Mr. Clements R. Markham were called into request by the home authorities.

Mr. Markham proposed a fourfold expedition to South America, and his scheme was at last sanctioned by the Secretary of State for India, and ordered to be carried out. The first portion of the expedition was directed t*a* Bolivia and Caravaya, the region of *Cinchona Calisay*o and *C. micrantha* (var. *Boliviana*). Secondly, Huanuco and Huamalies were to be searched for *C. nitida* and *C. glandulifera* Thirdly, Cuenca and Loxa in the Republic of Ecuador for *C. Chahuarguera*, *C. Uritusinga*, and *C. Condaminea*; and lastly, New Granada as the habitat of *C. pitayo* and *C. lancifolia*. Mr. Pritchett and Mr. Spruce were appointed coadjutors to Mr. Markham, and the expeditions set out in 1859, the latter gentleman proceeding to the northern part of Bolivia, the district of the yellow barks; Mr. Spruce to the mountain region of Chimborazo, in quest of red cinchonas; Mr. Pritchett taking the grey bark forests of Huanuco, in the north of Peru. The perils encountered by these travellers, the hardships they endured, the disappointments they suffered, form a chapter in the history of travel. But illness and privation, bad roads, and even native jealousies left unaffected the general success of the expedition, and though, unfortunately, the plants collected at great risk by Mr. Markham, including many of the best species of Bolivia, perished in the Red Sea in their transit to India, leaving no survivors, it is to the work accomplished by these three enthusiastic labourers that we owe the basis of our present Cinchona plantations. In 1860, the Ootamacund station was established, and the following year the number of young Cinchona trees was reported to be 1,128. Under the excellent care of Mr. McIvor these had been increased in 1863, the date to which I have brought my account of the Java plantations, to 248,166.

It is no part of my purpose to enter into minutiæ of history, nor to do more than associate with the first steps in Cinchona culture the names of Messrs. Hasskarl and Markham, Spruce, and Pritchett as travellers, those of Dr. De Vrij and Mr. John Eliot Howard as advisers in technical details, and more recently, Messrs. McIvor and

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[*] From the Address delivered at the Pharmaceutical Conference, Bradford, by Henry B. Brady, F.L.S., F.S.C., President.

[†] My friend, J. E. Howard, F.L.S., to whose kind revision subsequent paragraphs owe any scientific value they possess, tells me that, accuratel speaking, these were *C. Calisaya*, and var. *Josephiana*.